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(54) Rewritable data storage using carbonaceous material and writing/reading method therof

(57) A rewritable data storage using a carbonaceous material writes or erases information represented by the carbonaceous material (30) by means of a current induced electrochemical reaction on a conductive layer (20), by controlling a voltage applied across the space between cantilever tip (50) and the conductive layer. Also, the size of the carbonaceous material representing information is controlled by the level of the applied voltage or the application duration.

FIG. 1A

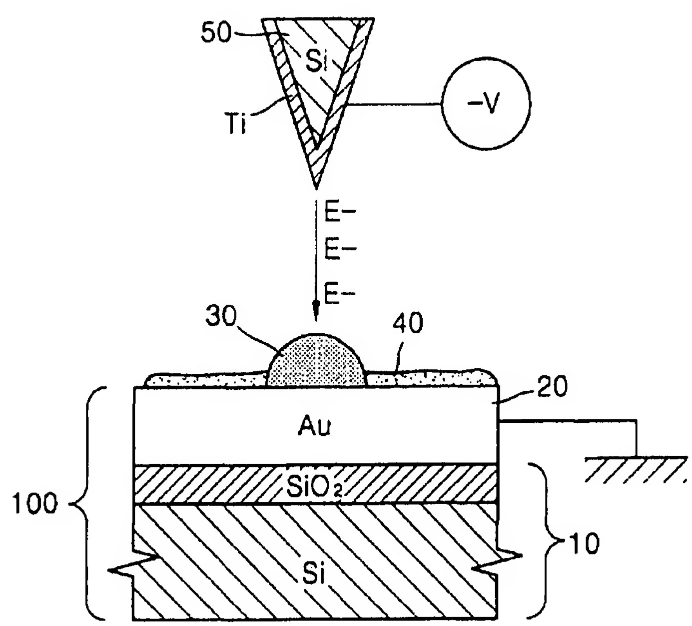
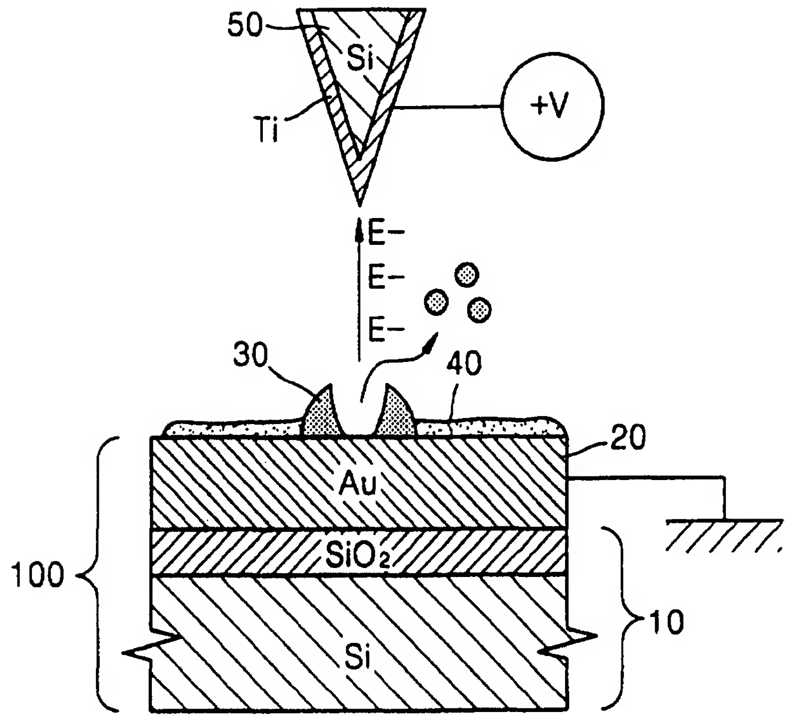


FIG. 1B



Description

[0001] The present invention relates to a rewritable data storage and a writing/reading method thereof, and more particularly, to a rewritable data storage using a carbonaceous material formed by controlling a bias voltage applied between a micro tip and a storage substrate and a writing/reading method thereof.

[0002] Conventional data storage methods include a ferroelectric substance polarization method, a polymer thermal transformation method, a magnetic substance phase transformation method, a resistant substance phase transformation method, a phase transformation method by oxidizing a metal or a semiconductor, and so on, but there are advantages and drawbacks with regard to writing time, data maintenance, and so on.

[0003] Some of these conventional methods are not rewritable, or even if the methods are rewritable, there are inevitable problems in that the material features are deteriorated by a write/erase cycle in which the recording medium undergoes phase transformation, and the endurance is low.

[0004] To solve the above problems, it is an objective of the present invention to provide a rewritable data storage using a carbonaceous material in which there are no problems that the endurance and the material features deteriorate because of phase transformation, and a writing/reading method thereof.

[0005] Accordingly, to achieve the above objective, there is provided a rewritable data storage using a carbonaceous material according to the present invention, including: a writing plate formed of a substrate and a conductive layer deposited on the substrate; and a tip for forming or eliminating carbonaceous material in the form of spots representing information recorded on the conductive layer.

[0006] In the present invention, preferably, the substrate is formed of SiO_2/Si, the conductive layer is formed by depositing Au, and the tip is formed by coating Ti on a tip-shaped Si core

[0007] Also, to achieve the above objective, there is provided a rewritable data storage using a carbonaceous material according to the present invention, including: a writing plate comprised of a substrate on which striped conductive layer patterns are formed on the substrate; and a tip disposed in an array having a regular interval to correspond to the striped conductive layer patterns along a cantilever extending across the striped conductive layer patterns in order to form or eliminate carbonaceous material in the form of spots representing information recorded on the conductive layer patterns.

[0008] In the present invention, preferably, the substrate is formed of SiO_2/Si, the conductive layer is formed by depositing Au, and the tip is formed by coating Ti on a tip-shaped Si core.

[0009] Also, to achieve the above objective, there is provided a writing/reading method of a rewritable data storage using a carbonaceous material according to the present invention, the rewritable data storage including a writing plate formed of a substrate and a conductive layer formed on the substrate, and a tip for forming or eliminating a carbonaceous material in the form of spots representing information recorded on the conductive layer, the writing/reading method including: (a) writing information by applying a predetermined bias voltage to a space between the tip and the conductive layer, and forming the carbonaceous material on the conductive layer, (b) erasing the information by applying a voltage of reverse polarity to the bias voltage applied in the step of writing to the space between the tip and the conductive layer, and eliminating the carbonaceous material already formed, and (c) reading the information by deciphering topography between the conductive layer and the carbonaceous material.

[0010] In the present invention, the size of the spot of the carbonaceous material formed in step (a) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer and the tip, or the time duration for which the bias voltage is applied. Likewise, the size of the spot of the carbonaceous material eliminated in step (b) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer and the tip or the time duration for which the bias voltage is applied. Also, the step (c) is preferably performed using one of a capacitance difference, a resistance difference, a frictional coefficient difference, and a height difference between the conductive layer and the carbonaceous material.

[0011] Also, to achieve the above objective, there is provided a writing/reading method of a rewritable data storage using a carbonaceous material according to the present invention, rewritable data storage including a writing plate comprising a substrate on which striped conductive layer patterns are formed by depositing a conductor on the substrate, and a tip disposed in an array having a regular interval to correspond to the striped conductive layer patterns in a cantilever extending across the striped conductive layer patterns in order to form or eliminate a carbonaceous material in the form of spots representing information recorded on the conductive layer patterns, the writing/reading method including: (a) writing information by positioning the cantilever, applying a predetermined bias voltage to the space between the tip of the cantilever and the selected conductive layer pattern and forming a carbonaceous material spot in a selected region on the selected conductive layer pattern; (b) erasing the information by positioning the cantilever, applying a voltage of reverse polarity to the bias voltage applied in the writing step to the space between the tip of the cantilever and the selected conductive layer pattern and eliminating the carbonaceous material already formed, and (c) reading the information by deciphering topography between the conductive layer pattern and the carbonaceous material.

[0012] In the present invention, the size of the spot of

the carbonaceous material formed in the step (a) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer pattern and the tip of the cantilever, or the time duration for which the bias voltage is applied. The size of the spot of the carbonaceous material eliminated in the step (b) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer pattern and the tip of the cantilever, or the time duration for which the bias pattern I applied. The step (c) is preferably decided using one of a capacitance difference , a resistance difference, a frictional coefficient difference, and a height difference between the conductive layer pattern and the carbonaceous material.

[0013] The above objective(s) and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIGS. 1A and 1B are drawings showing the basic structure and operation principle of a rewritable data storage using a carbonaceous material according to an embodiment of the present invention, and
FIG. 1A is a drawing showing a writing step;
FIG. 1B is a drawing showing an erasing step;
FIGS. 2A through 2D are images of a carbonaceous material actually formed using the principle illustrated in FIGS. 1A and 1B being read with an atomic force microscope (AFM), and
FIG. 2A is an image of a rectangular carbon microstructure being read with the AFM after writing the rectangular carbon microstructure on a metal layer by applying -6 V to a tip;
FIG. 2B is an image read with the AFM after erasing a part of the rectangular information of FIG. 2A (a black part of the center) by applying +5 V to the tip;
FIG. 2C is an image read with the AFM after reading FIG. 2B by applying +5 V to the tip and erasing three parts of the spot information;
FIG. 2D is an image read with the AFM after rewriting information in the center erased in FIG. 2B (a white point) by applying -6 V to the tip;
FIG. 3 is an image of carbonaceous material spots formed in the case of changing various magnitudes of bias voltage applied across the space between the substrate and the tip according to the method illustrated in FIGS. 1A and 1B being read with the AFM;
FIGS. 4A and 4B are graphs showing results of an Auger electron spectroscopy (AES) analysis in order to obtain an image of information written by the method illustrated in FIGS. 1A and 1B and the material constituents thereof; and
FIGS. 5A through 5C are drawings showing an example of applying the principle of the writing/reading method illustrated in FIGS. 1A and 1B to a wide area rewritable data storage.

[0014] Hereinafter, a rewritable data storage using a carbonaceous material and a writing/reading method thereof according to the present invention will be described in greater detail with reference to the appended drawings.

[0015] FIGS. 1A and 1B show the basic structure of an embodiment of a rewritable data storage using carbonaceous material according to the present invention. The rewritable data storage includes a substrate, for example, an SiO_2 substrate 10, and an Au/SiO_2/Si writing plate 100 formed by depositing a conductive layer 20 for example, Au on the substrate 10. In addition, a cantilever tip 50 is formed for forming or eliminating a carbonaceous material 30 in the form of spots representing information recorded on the conductive layer 20. Here, it is preferable to use a scanning probe microscope (SPM) series tip such as an AFM tip which is the cantilever tip 50 comprising Ti coated on the shape of an Si cantilever tip. Here, a reference numeral 40 is an ambient residual gas species such as CO_2, H_2O, O_2, N_2, CH_4 which can be obtained on the surface of the Au layer in air.

[0016] The rewritable data storage of the above structure employing a carbonaceous material, and the writing/reading method thereof are as follows.

[0017] If a bias voltage (V) is applied across the space between the cantilever tip 50 and the Au/SiO_2/Si writing plate 100, the carbonaceous material 30 is formed on the Au conductive layer 20. Here, if the level of the bias voltage applied across the space between the Au/SiO_2/Si writing plate 100 and the cantilever tip 50 is changed, the sizes of the carbonaceous material spots become different from each other. Information is read by detecting the shape of the carbonaceous material spots of different sizes.

[0018] That is, as illustrated in FIG. 1A, a bias voltage (-V) is applied across the space between the cantilever tip 50 and the conductive layer 20(an Au layer) of the portion required for writing using the cantilever tip 50 attached to the AFM, and the carbonaceous material 30 is formed. This step may be called "writing".

[0019] Also, as illustrated in FIG. 1B, a bias voltage of the reverse polarity (+V) is applied across the space between the cantilever tip 50 and the conductive layer 20 (an Au layer) of the portion required to be erased using the cantilever tip 50 attached to the AFM, and the carbonaceous material 30 is eliminated. This step may be called "erasing".

[0020] In addition, no voltage is applied when reading a record, topography between a deteriorated portion of the surface of the conductive layer (an Au layer) 20 and an intact portion or a difference in material features or a difference in electrical features is detected and read. This step may be called "reading". As this reading method, there can be various methods using a difference in physical features of the carbonaceous material 30 formed as spots by the voltage applied across the space between the cantilever tip 50 and the Au/SiO_2/Si writing plate 100, and the original conducive layer (an Au layer)

20.

[0021] For example, there are reading methods using topography between the carbonaceous material 30, formed by the bias voltage applied across the space between the cantilever tip 50 and Au/SiO_2/Si writing plate 100, and the original conductive layer portion (an Au layer) 20, a difference in capacitance, a difference in resistance, or a difference in frictional coefficient.

[0022] The structural principle of the rewritable data storage using the carbonaceous material as illustrated in FIGS. 1A and 1B is described in detail below.

[0023] There is provided the writing plate 100 comprising the conductive layer (an Au layer) 20 formed on the SiO_2/Si substrate 10, and the cantilever tip 50 comprising Ti coated on the tip-shaped Si core is disposed above the writing pad 100. Next, a regular voltage is applied across the space between the conductive layer 20 and the cantilever tip 50 of the writing plate, and electrons are emitted into the air (that is, an electric discharge is caused). The emitted electrons locally deposit the carbonaceous material on the conductive layer 20 of the writing plate through an electrochemical reaction with CO_2, H_2O, N_2, O_2, CH_4, and so on existing in the air on the conductive layer 20 of the writing plate 100. If the written information is erased, the electrochemical reaction (or a voltage or a current induced electrochemical decomposition/desorption) is caused by applying the voltage of reverse polarity, and the stored carbonaceous material 30 is eliminated from the conductive layer 20.

[0024] When reading a difference between written information and erased information, it is read by detecting topography between the original conductive layer and the grown carbonaceous material.

[0025] Images of the actually formed carbonaceous materials being read with the AFM are illustrated in FIGS. 2A through 2D.

[0026] FIG. 2A is an image of a rectangular carbon microstructure being read by applying -6 V to the tip after writing the carbon microstructure on the Au layer. FIG. 2B is an image of the rectangular form of FIG. 2A being read with the AFM after erasing a part, leaving a black part in the center, by applying +5 V to the tip. FIG. 2C is an image of the rectangular structure being read with the AFM after erasing three more parts of the original spot form by applying +5 V to the tip. FIG. 2D is an image of the rectangular structure being read with the AFM after rewriting information (a white point) in the center which was previously erased, by applying -6 V to the tip. As sequentially illustrated in FIGS. 2A through 2D, the process, wherein the carbonaceous material 30 is formed in a specified region on the writing plate 100 (a conductive layer), the formed material is erased, and then the carbonaceous material is formed again in the same position, can be performed by the polarity transformation of the bias voltage applied across the space between the cantilever tip 50 and the conductive layer 20.

[0027] FIG. 3 is an image of spots of the carbonaceous material formed when changing and applying various sizes of the bias voltage applied across the space between the substrate and the tip being read with the AFM. Here, it is shown that the spots of the formed carbonaceous material can be formed to various sizes according to the size of the applied bias voltage or the duration of application.

[0028] Therefore, in FIGS. 2A through 2D, the size of the spot of the carbonaceous material formed or eliminated can be controlled by changing the magnitude of the bias voltage as illustrated in FIG. 3. Particularly, the size of the spot can be controlled on the order of tens nm, so that it can be easily applied to the manufacture of a rewritable data storage of hundreds or more Gb class.

[0029] Referring to FIGS. 4A and 4B, the results of an Auger electron spectroscopy (AES) analysis will be described in order to ascertain material constituents of the written information. FIG. 4A is an image of a sample used for the AES analysis being read with the AFM, wherein a white part of size 3 $\mu m \times 4 \mu m$ (P3, P4) is a place where the carbonaceous material is formed by the method previously described (where information is stored), and the conductive layer region where the carbonaceous material is not formed is indicated as P1, P2. AES spectrums indicated as P3 and P4 in FIG. 4B are the result of an AES analysis of a place where information is stored. AES spectrums indicated as P1 and P2 in FIG. 4B are the result of an AES analysis of the original Au layer where information is not stored.

[0030] While in P1, P2 where information is not stored, a large quantity of Au and carbon constituents are detected, in P3, P4 where information is stored, almost no Au is detected and only a large quantity of carbon constituents are detected. Therefore, it can be concluded that a rewritable data storage mechanism according to the present invention involves the local deposition/removal of carbonaceous material on the Au layer by the current induced electrochemical reaction as described above.

[0031] Referring to FIGS. 5A through 5C, an example of applying the principle of the writing/reading method to a wide rewritable data storage will be described. As illustrated in FIG. 5A, striped conductive layer patterns 210 are formed on a substrate 200, a cantilever 225, in which a cantilever tip 220 is formed in an array, is installed above the conductive layer patterns to form a circuit, and then, the carbonaceous material can be formed in the desired place. Also, information of the desired place can be read by selecting a switch 211 and a position of the cantilever, and applying a voltage. That is, as illustrated in FIG. 5B, if the bias voltage is not applied across the space between the cantilever tip 220 and the conductive layer patterns 210, the carbonaceous material is not formed. However, as illustrated in FIG. 5C, if the cantilever tip 220, such as AFM tip, and the third conductive layer pattern 210 are selected and a bias voltage (-6 V) is applied, the carbonaceous material 230

is formed in the selected region of the selected third conductive layer pattern 210. Hereby, even though the storage has a wide area, information can be written/read by accessing the desired region.

[0032] Also, a plurality of cantilevers, on each of which tips are formed in an array, may be formed so that a data storage capable being accessed while the cantilevers move only a short distance, can be manufactured.

[0033] As described above, a rewritable data storage using carbonaceous material according to the present invention writes or erases information, that is the carbonaceous material, by means of a current induced electrochemical reaction on the conductive layer, by controlling a voltage applied across the space between the cantilever tip and the conductive layer. Also, here, the size of the carbonaceous material representing information is controlled by the level of the applied voltage or the application duration.

[0034] Therefore, because the data storage is rewritable but does not employ phase transformation, the writing/erasing endurance is enhanced, and the deterioration of the material features of the prior art with respect to a continuous write/erase cycle is solved, so that it can be semi-permanently used. Moreover, information can be stored and eliminated by creating or eliminating a structure on the order of tens of nanometers in size, so that a rewritable data storage capable of storing and rewriting more than hundreds of gigabytes of information Gb can be embodied.

Claims

1. A rewritable data storage using a carbonaceous material comprising:

    a writing plate formed of a substrate and a conductive layer deposited on the substrate; and
    a tip for forming or eliminating carbonaceous material in the form of spots representing information recorded on the conductive layer.

2. The rewritable data storage using a carbonaceous material of claim 1, wherein the substrate is formed of SiO_2/Si.

3. The rewritable data storage using a carbonaceous 'material of claim 1 or 2, wherein the conductive layer is formed by depositing Au.

4. The rewritable data storage using a carbonaceous material of claim 1, 2 or 3, wherein the tip is formed by coating Ti on a tip -shaped Si core.

5. A rewritable data storage according to any preceding claim wherein the conductive layer includes striped conductive layer patterns formed on the substrate; and

    a cantilever extending across the striped conductive layer patterns carrying an array of tips having a regular interval to correspond to the striped conductive layer patterns for forming or eliminating carbonaceous material in the form of spots representing information recorded on the conductive layer patterns.

6. A writing/reading method of a rewritable data storage using a carbonaceous material, the rewritable data storage including: a writing plate formed of a substrate and a conductive layer formed on the substrate; and a tip for forming or eliminating a carbonaceous material in the form of spots representing information recorded on the conductive layer, the writing/reading method comprising:

    (a) writing information by applying a predetermined bias voltage to the space between the tip and the conductive layer and forming a carbonaceous material on the conductive layer;
    (b) erasing the information by applying the voltage of reverse polarity to the bias voltage applied in the writing step to the space between the tip and the conductive layer, and eliminating the carbonaceous material already formed; and
    (c) reading the information by discriminating topography between the conductive layer and the carbonaceous material.

7. The writing/reading method of the rewritable data storage using the carbonaceous material of claim 6, wherein, the size of spots of the carbonaceous material formed in step (a) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer and the tip or the time duration for which the bias voltage is applied.

8. The writing/reading method of the rewritable data storage using the carbonaceous material of claim 6 or 7, wherein the size of spots of the carbonaceous material eliminated in step (b) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer and the tip or the time duration for which the bias voltage is applied.

9. The writing/reading method of the rewritable data storage using the carbonaceous material of claim 6, 7 or 8, wherein the step (c) is performed using one of a capacitance difference, a resistance difference, a frictional coefficient difference, and a height difference between the conductive layer and the carbonaceous material.

10. A writing/reading method of a rewritable data storage according to any of claims 6 to 9 wherein the

writing plate comprises a substrate on which striped conductive layer patterns are formed by depositing a conductor on the substrate; and a cantilever extends across the striped conductive layer patterns carrying an array of tips having a regular interval to correspond to the striped conductive layer patterns for forming or eliminating a carbonaceous material in the form of spots representing information recorded on the conductive layer, including:

(a) writing information by positioning the cantilever, applying a predetermined bias voltage to the space between the cantilever tip and the selected conductive layer pattern and forming a carbonaceous material in the selected region of the selected conductive layer pattern; and
(b) erasing the information by positioning the cantilever, applying the voltage of reverse polarity to the bias voltage applied in the writing step to the space between the cantilever tip and the selected conductive layer pattern, and eliminating the carbonaceous material already formed.

11. The writing/reading method of a rewritable data storage using a carbonaceous material of claim 10, wherein the size of spots of the carbonaceous material formed in step (a) is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer patterns and the cantilever tip, or the time duration for which the bias voltage is applied.

12. The writing/reading method of the rewritable data storage using the carbonaceous material of claim 10 or 11, wherein the size of spots of the carbonaceous material eliminated in the step 10 or 11 is decided by controlling the magnitude of the bias voltage applied across the space between the conductive layer patterns and the cantilever tip, or the time duration for which the bias voltage is applied.

FIG. 1A

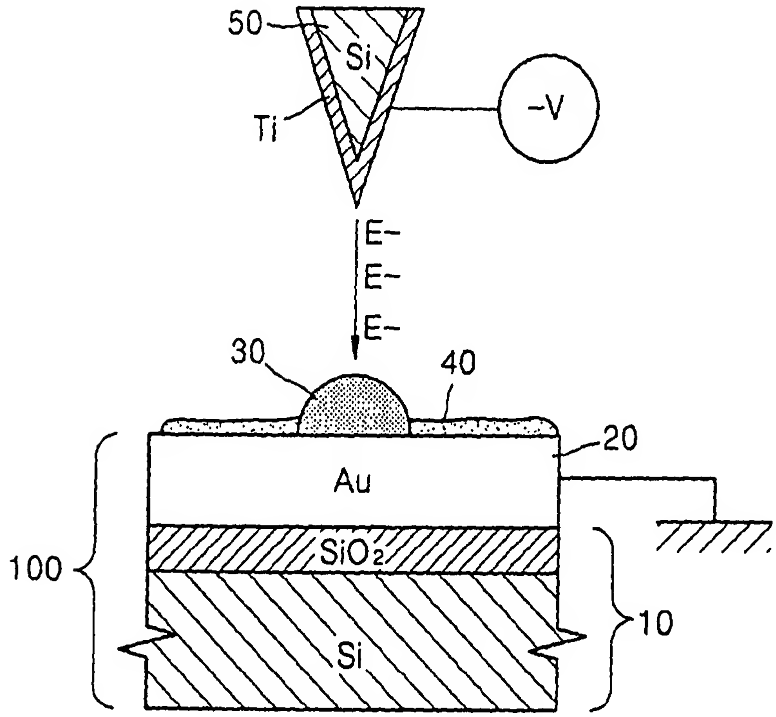

50
Si
Ti
-V
E-
E-
E-
30
40
20
Au
SiO2
100
10
Si

FIG. 1B

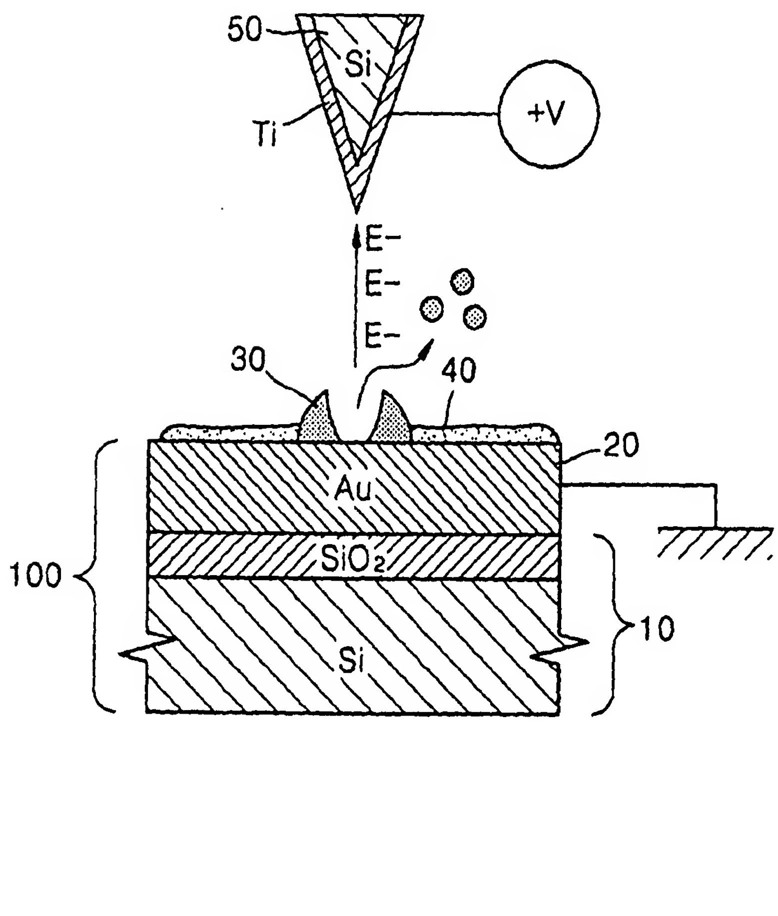

50
Si
Ti
+V
E-
E-
E-
30
40
20
Au
SiO2
100
10
Si

FIG. 2A

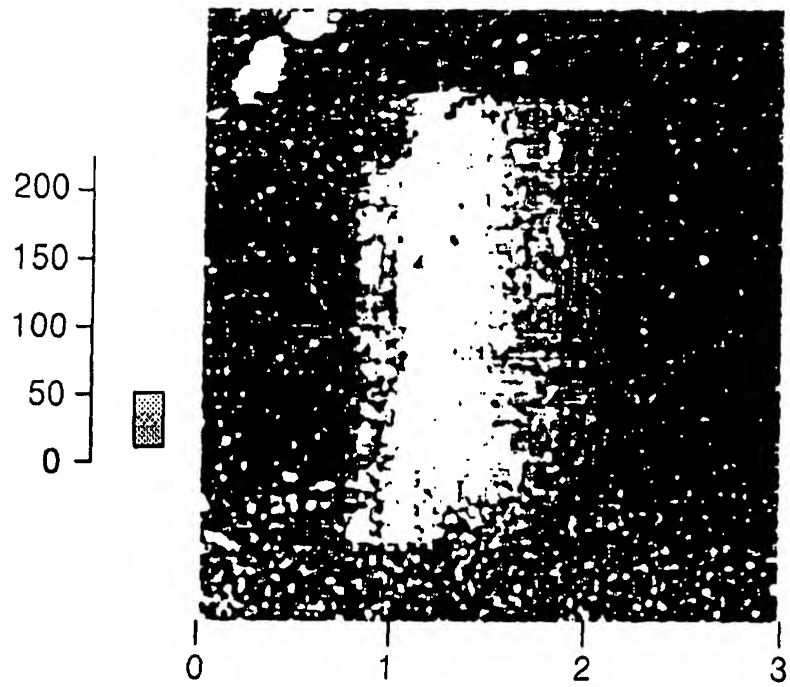


FIG. 2B

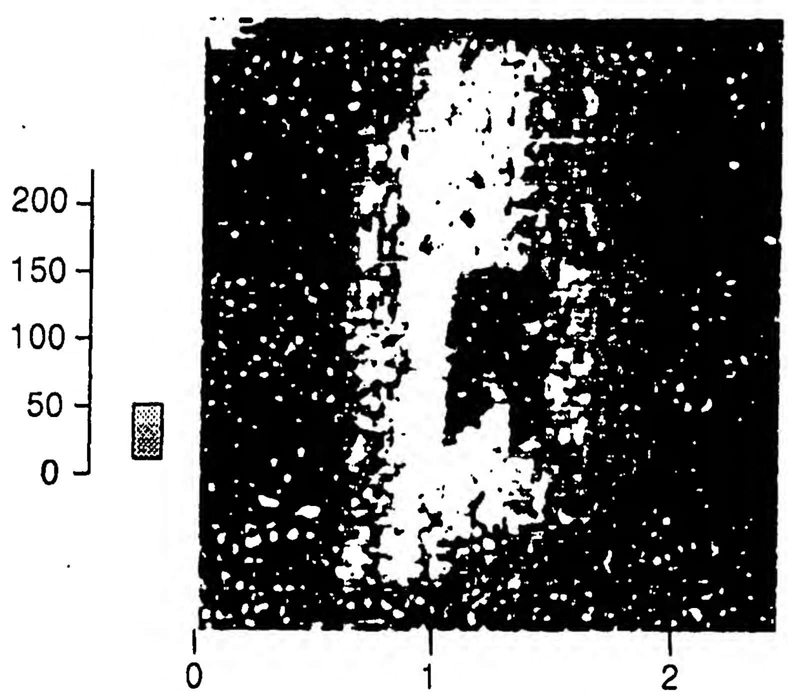


FIG. 2C

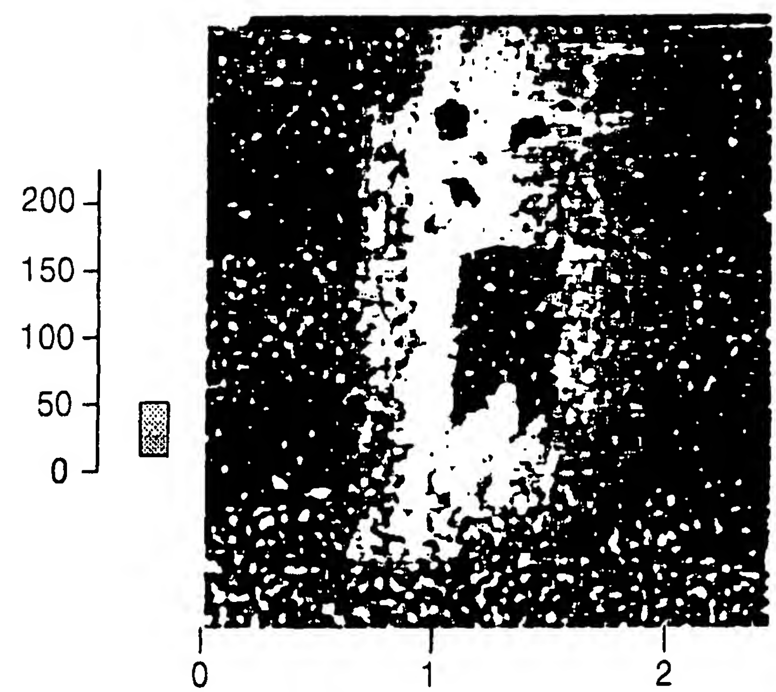
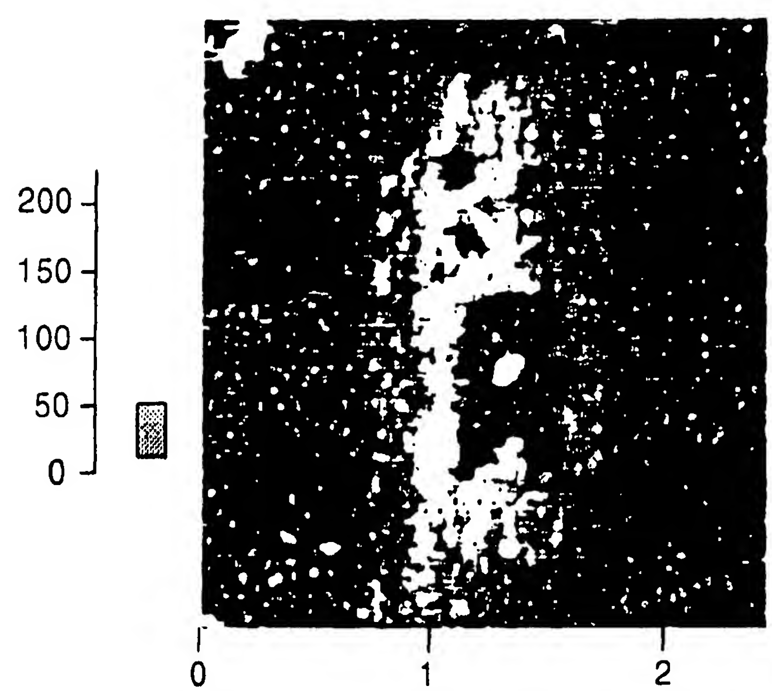


FIG. 2D



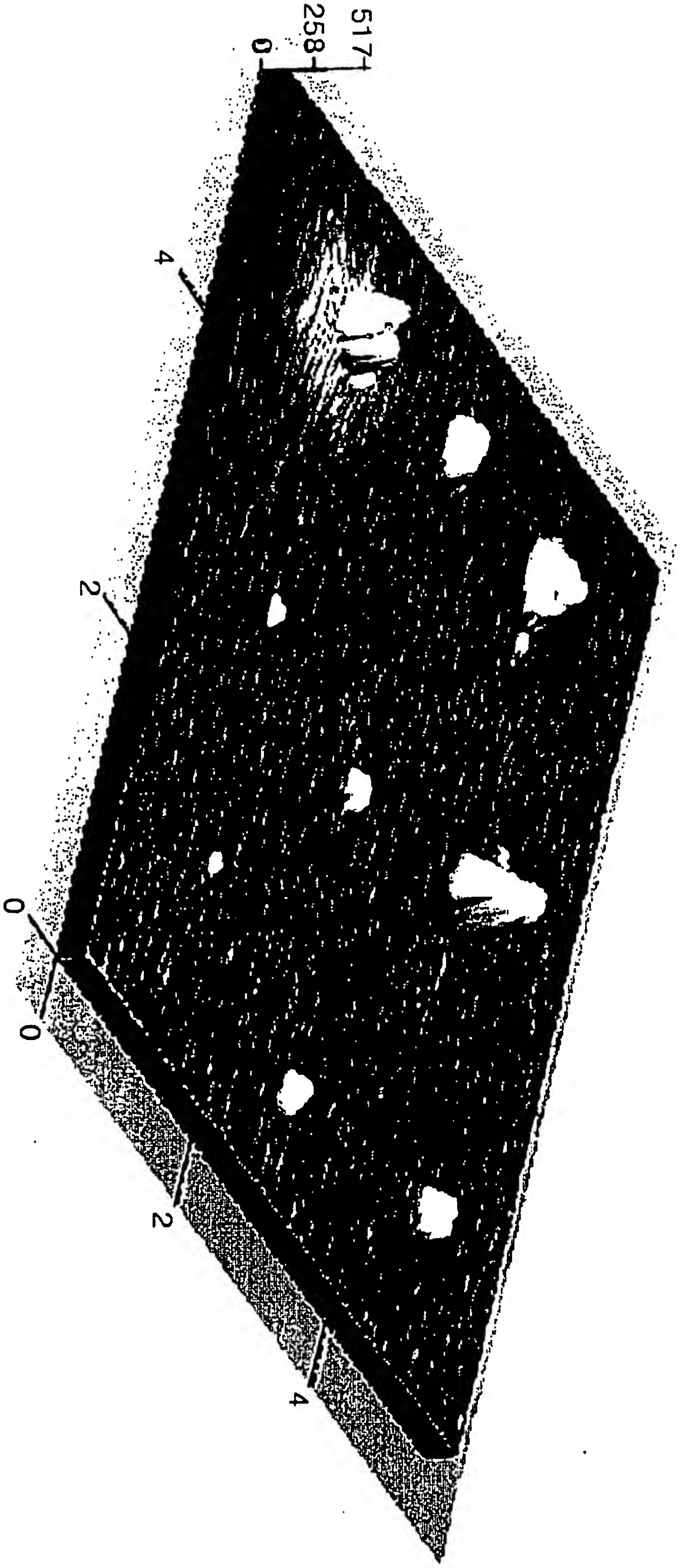


FIG. 3

FIG. 4A

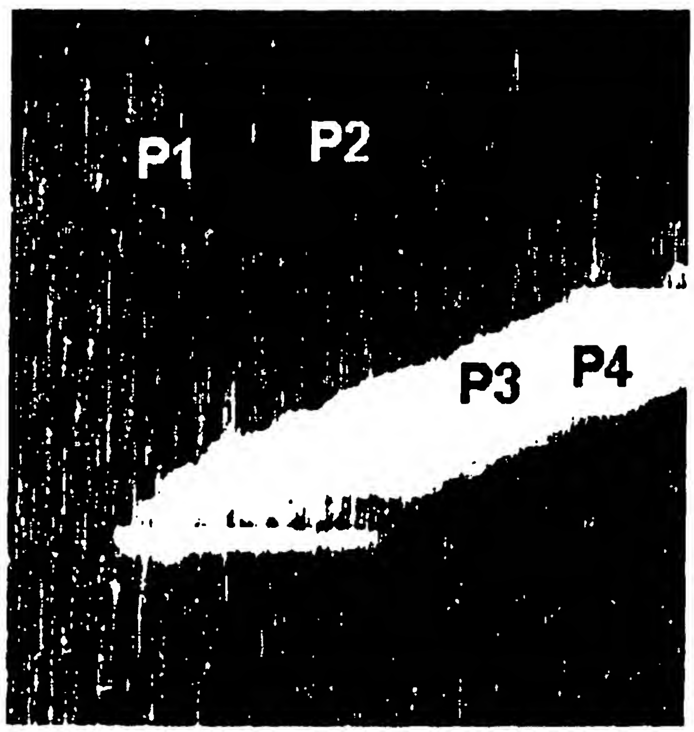


FIG. 4B

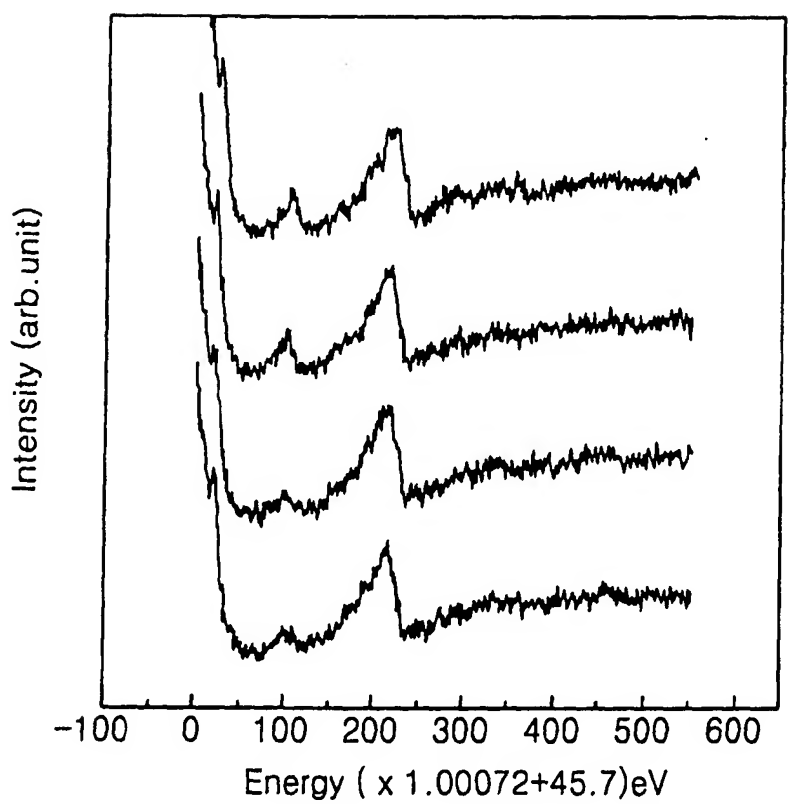

Intensity (arb.unit)
−100 0 100 200 300 400 500 600
Energy (x 1.00072+45.7)eV

FIG. 5A

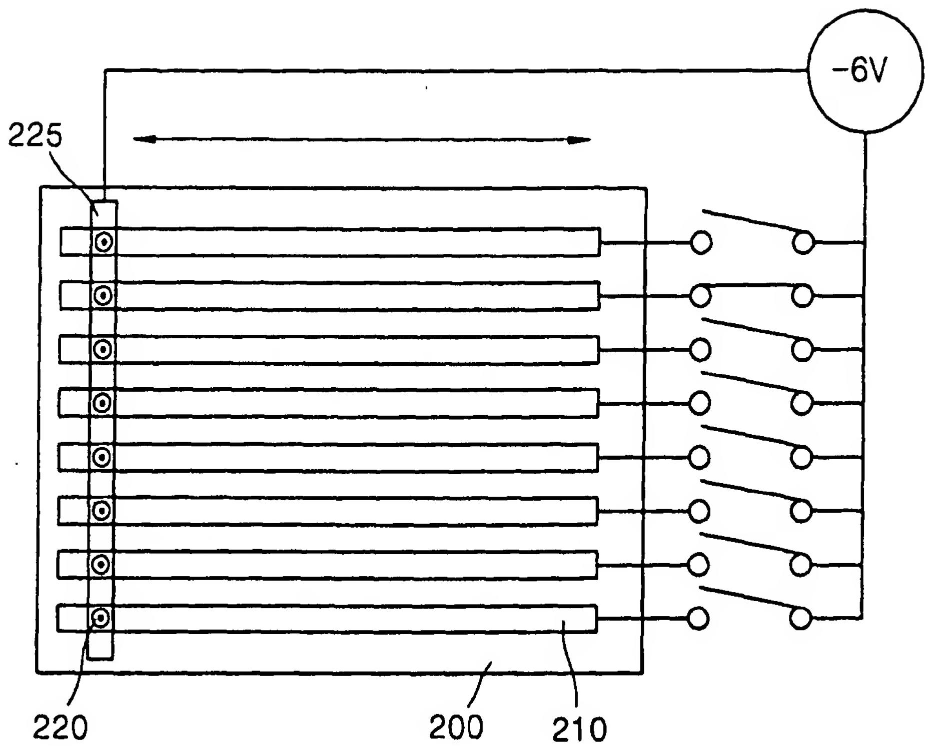


FIG. 5B

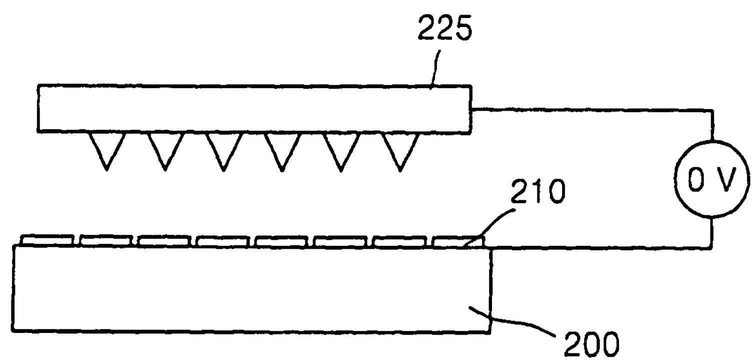


FIG. 5C